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INVESTIGATIONS OF CATERPILLARS ATTACKING TOMATOES IN NORTHERN CALIFORNIA DURING 1939

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INVESTIGATIONS OF CATERPILLARS ATTACKING TOMATOES IN NORTHERN CALIFORNIA DURING 1939[1]

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THE TOMATO is subject to attack by many different kinds of caterpillars, a number of which are capable of inflicting serious injury. There are some species that are mainly a pest of the fruit, while others are destructive because of the defoliation they cause. Caterpillars that attack the fruit may cause losses in two ways: not only is the fruit that is seriously attacked made unfit for the market, but also decay-producing organisms may find a portal of entry into even slightly injured fruit. A tolerance has been placed on the number of insect parts allowed in a given unit of processed tomatoes, and because of this it is highly desirable to deliver tomatoes to the cannery as free of worms as possible. Defoliating caterpillars not only reduce the size of the vines, but they also expose the fruit, which frequently results in serious sunburning of the fruit. If not controlled, caterpillars may reduce a profitable crop to one that will result in a loss to the grower.

Interest in these caterpillars has made it advisable to continue the studies started in 1935, particularly those concerned with corn earworm. Results of investigations previous to 1939 have been reported by Michelbacher and Essig (1938, 1939).[5] The information presented here supplements the previous work.

OCCURRENCE OF VARIOUS INSECTS DURING THE 1939 SEASON

The Tomato Pinworm.—The tomato pinworm, *Gnorimoschema lycopersicella* Busck, has not proved to be a serious pest in the northern tomato-producing section of California. In 1939 it was taken in only three out of thirteen counties surveyed (table 1), whereas in 1938 it was found in six out of ten counties. It was abundant only in Madera and Merced counties, where the loss incurred was not great because harvest

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[5] See "Literature Cited" at the end of this paper for complete data on citations, which are referred to in the text by author and date of publication.

had been completed a month or more before the insects became abundant. Most of the tomatoes in this area are grown for the early-summer trade, and, according to Mr. Kingsley, Agricultural Commissioner of Merced County, the shipping season always ends by the first of August. The major part of the crop was therefore harvested before the pinworm populations built up to sufficient numbers to cause serious losses. During

TABLE 1

PROPORTIONS OF TOMATOES INFESTED BY TOMATO PINWORM, POTATO TUBER MOTH, AND CORN EARWORM IN THIRTEEN COUNTIES OF NORTHERN CALIFORNIA, 1939

County and date of survey	Number of fields examined	Tomato pinworm		Potato-tuber-moth larva		Corn earworm	
		Range	Average	Range	Average	Range	Average
Alameda, October 2	21	0.0– 0.0	0.0	0.0– 5.5	0.5	0 0–12.3	5.7
Contra Costa, October 30	16	0.0– 0.0	0.0	0.0– 1.5	0.1	0.5–20.0	6.9
Madera, October 3	7	1.7–72.2	28.1	0.0– 0.0	0.0	0.0–21.0	3.4
Merced, October 9	9	5.3–91.0	32.7	0.0– 0.0	0.0	0.3– 8.0	3.3
Monterey, October 18	12	0.0– 0.0	0.0	0.0– 5.0	2.7	1.0–28.5	8.5
Sacramento:							
September 13	11	0.0– 0.0	0.0	0.0– 0.0	0.0	0.5– 6.0	3.0
October 26	11	0.0– 0.0	0.0	0.0– 0.0	0.0	0.7–16.8	6.1
San Benito, October 17	13	0.0– 0.0	0.0	0.0– 3.0	0.5	0.5–10.0	4.0
San Joaquin, October 13	14	0.0– 0.0	0.0	0.0– 4.0	0.5	0.5–10.0	3.3
Santa Clara:							
September 18	14	0.0– 0.0	0.0	0.0– 1.0	0.1	0.5–21.3	5.7
October 31	8	0.0– 0.5	0.1	0.0–10.0	1.8	0.3–12.0	5.6
Santa Cruz, October 19	10	0.0– 0.0	0.0	0.5–11.7	4.0	3.5–28.5	12.2
Solano, October 24	11	0.0– 0.0	0.0	0.0– 0.0	0.0	0.0–11.5	3.5
Stanislaus, October 10	10	0.0– 0.0	0.0	0.0– 0.5	0.1	0.0–10.0	4.1
Yolo:							
September 14	12	0.0– 0.0	0.0	0.0– 0.0	0.0	2.0–14.0	5.0
October 27	16	0.0– 0.0	0.0	0.0– 0.3	0.0	0.0–15.0	3.6

the past season, Mr. Kingsley reported that although a careful check was made, no specimens were observed until July 10, when only two were found in a large number of tomatoes. All evidence obtained indicates that a late crop in these two counties would in all probability be heavily attacked, and it would certainly seem unwise to grow a late shipping or canning crop of tomatoes in this area.

In Madera and Merced counties some interesting observations were made on the pinworm in the San Marzano, a pear-shaped tomato. This variety was severely attacked: in one field in which it and shipping tomatoes were found growing side by side, 29 per cent of the shipping tomatoes and 20.2 per cent of the San Marzano were infested. But since the latter sets much more heavily than most other varieties, the total number of infested fruits was probably as great as in the shipping toma-

toes. The injury done by the pinworm to the San Marzano was not easy to detect, particularly in the early stages, and it would be practically impossible for the pickers to discard infested fruits in the field. This may account for the fact that, late in the season, loads of this variety coming from Merced County were being rejected at the cannery.

The pinworm has not been numerous in any area outside of Madera and Merced counties and in no case has the infestation exceeded 0.5 per cent in the coastal areas. It was found most abundant in 1937. In 1938 there was a marked decrease and the past season it almost disappeared. It seems probable that there are environmental factors unfavorable for the development of the pest. The failure of the pinworm to become destructive at any time during the past four years indicates that this insect will not become a problem in northern California outside of the Madera-Merced region. The pest has never been found in the large tomato-growing region that embraces Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties nor has it been taken in either Santa Cruz or Monterey counties.

The distribution of the pinworm in the area surveyed during the past season is shown in figure 1.

The Potato Tuber Moth.—Widespread throughout the northern tomato-producing section of California (table 1), the potato tuber moth, *Gnorimoschema operculella* (Zeller) (*Phthorimaea*), was taken in nine out of the thirteen counties surveyed in 1939, although in most of them it was not numerous. The largest numbers were found in the coastal counties. The only commercial damage observed was in a single field in Santa Cruz County; here the infestation was so severe that the grower hesitated to harvest the ripe fruit for fear it would be rejected at the cannery. The crop had been grown for green shipment, but sufficient tomatoes had ripened so that the loss to the grower was 3 or 4 tons to the acre.

Two surveys made in Santa Clara County indicated that the infestation did not develop until late in the season. On September 18, 1939, the pest could be found only with difficulty, and while it was more abundant on October 31, no serious damage was being done.

Tomato and Tobacco Hornworms.—The tomato hornworm, *Protoparce sexta* (Johan.), and the tobacco hornworm, *P. quinquemaculata* (Haw.), caused very little damage in the northern tomato-producing section in 1939. Less injury was encountered than at any time since 1935 when this investigation was started, and few or no control measures were necessary. In experimental work, undiluted calcium arsenate dust has been very effective in controlling both of these caterpillars. Hornworms

are among the most destructive caterpillars attacking tomatoes over a large part of the tomato-growing section, and the reduction in damage this past season meant a considerable saving to producers.

Armyworms.—The beet armyworm, *Laphygma exigua* (Hbn.), was

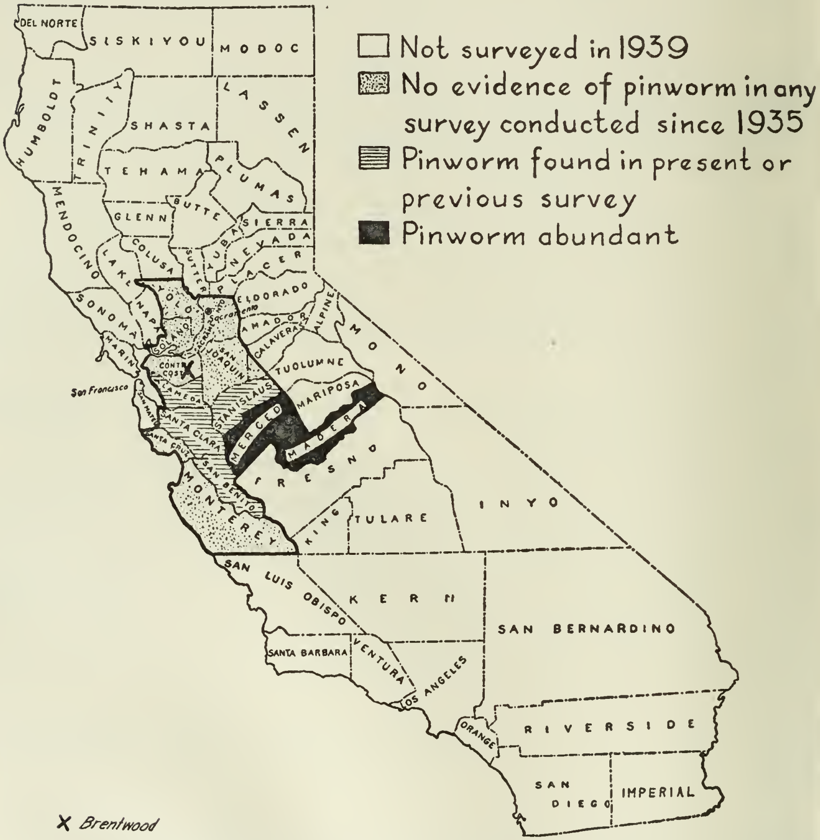

Fig. 1.—Distribution of the tomato pinworm, *Gnorimoschema lycopersicella* Busck, in the thirteen counties surveyed in the northern tomato-producing section of California in 1939. Outside of the area surveyed the pinworm is probably abundant in the southern portion of the San Joaquin Valley and in parts of southern California.

more abundant during 1939 than at any other time since these studies were started. It is primarily a foliage feeder although it frequently injures the fruit; but since it is characteristically an external feeder, fruit injury is usually superficial. It was so abundant in some fields that there was noticeable defoliation and fruit injury. Damage from its attacks was most serious where the fruit was grown for the green market.

The yellow-striped armyworm, *Prodenia praefica* Grote, was not a serious pest during 1939. Not a single field was encountered in which it was doing damage. This caterpillar is a defoliator, but may also seriously injure the tomato fruit. It feeds externally on the tomato and does not enter the fruit. The larvae consume large amounts of food, and where an infestation is heavy, serious damage occurs.

During 1939 fruit in several fields was injured by armyworms of some undetermined species, belonging to that group which lives in the soil or in the debris that covers it and comes out to feed only at night. When numerous, this type of armyworm may be controlled with poison baits scattered on the soil in the early evening. The fruit which rests on the ground is most often attacked although the caterpillars also may crawl up the vines and feed.

Alfalfa Looper.—The alfalfa looper, *Autographa californica* (Speyer), was found rather generally distributed throughout the area surveyed in 1939, but, as in other years, no feeding was observed that would necessitate any control measures. This caterpillar attacks the foliage and seldom feeds on the fruit.

Corn Earworm.—The corn earworm, *Heliothis armigera* Hbn., also known as *H. obsoleta* (Fab.), is the most destructive caterpillar attacking tomato fruits in the northern section of California. This pest extends over the entire area where tomatoes are grown, but the intensity of its attack varies both from year to year and from district to district during the same year. One region may suffer serious damage, while in adjacent sections the pest may be of no importance. Several stages in its life history are shown in figure 2.

Fruits which have been severely injured are easily recognized (fig. 3) and can be discarded, but fruits infested with small larvae in the earlier stages of development are difficult to detect. The problem which these obscure injuries create for the grower, shipper, and canner is probably more important than the loss occasioned by complete destruction of the fruits.

The results of the survey in the thirteen counties visited in 1939 (table 3) showed that the infestation was much more severe than that encountered in 1938. As in other years, evidence indicated that the infestation did not set in until rather late in the season. In several places control measures probably played an important part in reducing the seriousness of the infestation. Throughout the area surveyed, marked variations were noted in the degree of infestation. Areas of lowest infestation appeared to be mostly those regions where tomatoes were grown under dry-farming conditions although in some places low popu-

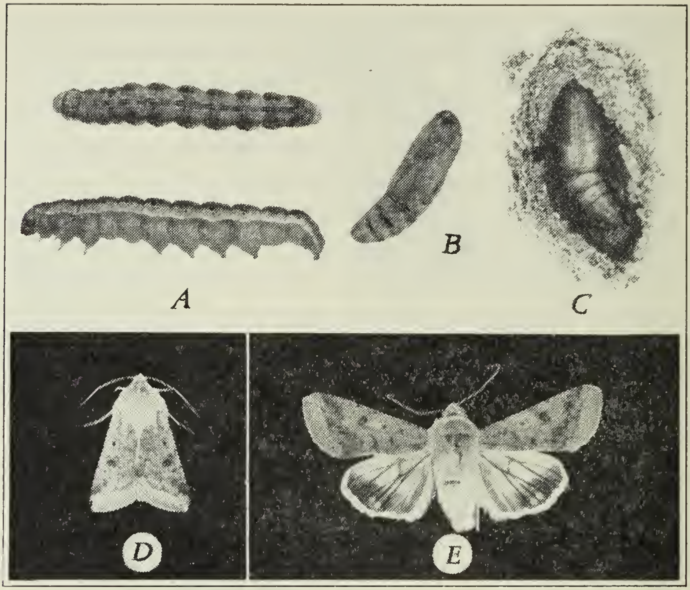

Fig. 2.—Stages in the life cycle of the corn earworm: *A,* mature larvae; *B,* pupa removed from earthern cell; *C,* pupa within earthen cell; *D,* adult in a position of rest; *E,* adult with wings spread. (All natural size.)

Fig. 3.—Corn-earworm damage to tomatoes: *A,* advanced injury of the stem end with caterpillar in burrow; *B,* tomato cut in half to show the internal destruction caused by the caterpillar. (From Ext. Cir. 99.)

lations were found in irrigated regions. The heaviest infestations encountered were found in shipping tomatoes near Salinas and Watsonville, where, in general, no effective control measures had been attempted. Worminess in these fields amounted to as much as 28.5 per cent of the fruit.

Parasitism may have played a part in the fluctuations noted. *Hyposoter exiguae* (Vier.) (fig. 4), the adults of which can be seen flying about the tomato vines, is a very important hymenopterous parasite of corn-earworm larvae. Very small larvae are attacked and frequently large portions of the corn-earworm population are parasitized.

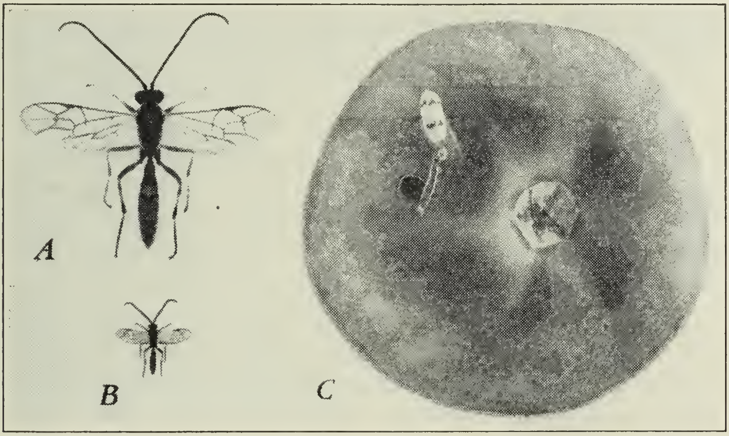

Fig. 4.—*Hyposoter exiguae* (Vier.), an important hymenopterous larval parasite of the corn earworm: *A*, adult enlarged three times; *B*, adult natural size; *C*, tomato showing cocoon of parasite with larval skin of the corn earworm attached, natural size.

FLIGHT HABITS OF THE CORN EARWORM

During 1939, several observations on the behavior of the corn earworm were made. Usually corn-earworm moths do not become active until just before dusk, but on two occasions moths were observed laying eggs in the early afternoon on clear bright days.

Apparently corn-earworm moths are capable of two different kinds of flights. If emergence occurs in an area where there is ample food in a suitable condition for oviposition, the insect will remain in that area and will make only short flights. If, on the other hand, the adults on emerging find no suitable host plants for oviposition, they may make long flights to other suitable breeding grounds. During these prolonged flights, the moth may actually go beyond points where the first suitable host plants are encountered. There is some evidence in support of this belief. Cockerell (1914) reported that moths were taken in large numbers at lights at Boulder, Colorado, and that all evidence indicated that they had flown in from a distance of several hundred miles. Stanley (1932) also collected corn-earworm adults at lights on the tops of the two highest buildings in Knoxville, Tennessee.

At Modesto, on October 10, seven corn-earworm moths were found near well-lighted stores. None of these insects were badly rubbed and, since they were at a considerable distance from any apparent point of origin, it is possible that they may have been attracted to the lights while on a migratory flight. Migrations of this type may be partially responsible for some of the late infestations that occur in tomato fields.

Conditions favoring migratory flights are found in the northwest portion of the San Joaquin Valley: a large acreage of baby lima beans is grown in this area. Although this crop has not been seriously damaged by the corn earworm, the latter breeds upon the bean plants, and on account of the extensive acreage a very large population develops. The bean harvest is well under way by September 1, and by September 15 few fields are in a stage of growth suitable for oviposition. There must be a heavy moth emergence, and the only food plants over a wide area are alfalfa and scattered truck crops. Moths emerging in such an area may migrate and establish infestations at a distance. In most tomato fields, corn-earworm infestations occur late in the season, usually not before the first of August. Corn-earworm infestations at Brentwood have not become serious until about the time the baby-lima-bean crop in the northwest portion of the San Joaquin Valley no longer serves as food for the insect. Hence, it seems probable that corn-earworm populations may build up on other crops and then move to tomatoes.

FIELD EXPERIMENTS TO DETERMINE CONTROL MEASURES FOR THE CORN EARWORM

Amount of Infestation in Untreated Plots.—For the past four years, field tests of insecticides to prevent tomato-fruit injuries have been conducted in the area around Brentwood (see fig. 1). The data presented in figure 5 show that injuries to fruits on untreated plants in the 1939 season were far more numerous than at any other time during the past four years. From the same graph, it is apparent that the infestation, as judged by resulting fruit injuries this past year, started earlier, built up more rapidly, and was at its peak from mid-September to late October. The degree of injury varies greatly from year to year and from field to field in any given year, as would be expected. Consequently, each field must be examined carefully to determine the need and time for applying control measures.

Only those fruits actually *infested* with worms were used in constructing the graphs in figure 5; those fruits which were "stung" or superficially injured were not included, although this type of injury generally equals or exceeds that which is classified as wormy. Some of the super-

ficial injury is caused by the corn earworm although most of it is done by beet armyworm and other caterpillars.

The experimental work in 1939 was carried on in fields where the

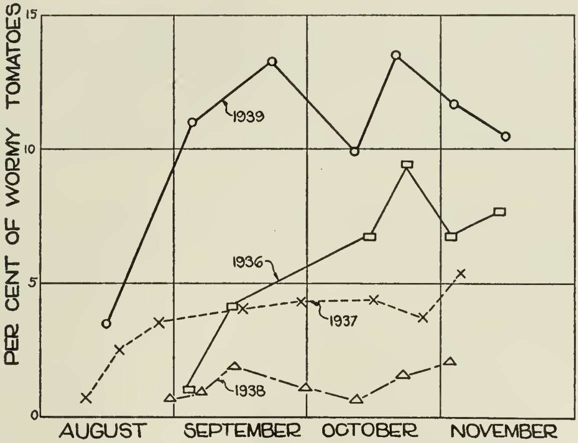

Fig. 5.—Corn-earworm injury to tomatoes on untreated plots at Brentwood during the years 1936–1939 inclusive.

Pearson variety was being grown for eastern shipment. The wormy, the superficially injured, and the total number of injured fruits observed

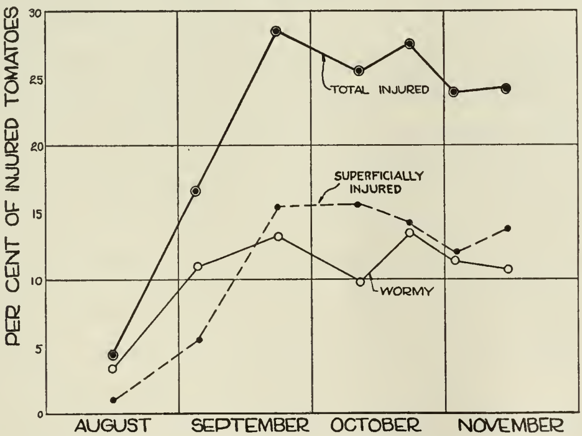

Fig. 6.—Amount of fruit injured by caterpillars (lepidopterous larvae) during the 1939 season in the check plots at Brentwood.

on untreated plants in the check plots at Brentwood are shown in figure 6. The total injuries to untreated fruits during the harvest period averaged slightly more than 25 per cent.

Insecticide Applications.—A random distribution of plots each 60 feet square, with each treatment replicated four times, was used for the insecticide tests. The plants were in rows 6 feet apart and 4 feet apart in each row, so that there were 150 plants in each plot if none were missing. The experimental series consisted of the four treatments shown in table 2 and corresponding check plots. The cryolite dusts were diluted with talc to the proportions shown in the table. The plots were dusted three times when suitable weather conditions prevailed. A bellows type

TABLE 2

INSECTICIDES USED AT BRENTWOOD, 1939

Insecticides		Amounts used in pounds per acre					
		September 8		September 27		October 12	
Dust	Per cent active ingredient	Dust	Active ingredient	Dust	Active ingredient	Dust	Active ingredient
Commercial calcium arsenate	26.7 arsenic	12	3.2 arsenic	11	2.9 arsenic	17	4.5 arsenic
80 per cent cryolite*	43.2 fluorine	16	6.9 fluorine	18	7.8 fluorine	18	7.8 fluorine
40 per cent cryolite*	21.6 fluorine	19	4.1 fluorine	21	4.5 fluorine	20	4.3 fluorine
40 per cent cryolite* (extra-heavy application)	21.6 fluorine	33	7.1 fluorine	28	6.0 fluorine	39	8.4 fluorine

* Natural cryolite from Greenland, containing 54 per cent fluorine.

of duster was used for the first two applications and a rotary duster for the last application. The dusters were weighed before and after treating each plot to determine the amounts of materials used. The average amounts of dust applied on an acre basis for each of the three dustings and for each of the treatments, together with the dates of applications, are also given in table 2. On September 30, a light rain (0.10 inch) fell at Brentwood, but apparently the section where the experimental plots were located received less and the dust was not washed from the vines. On October 2, 1.03 inches of rain fell and on October 5, another 0.33 inch was added. These rains washed the dust from the vines and between October 5 and October 12, there was little protection against worms.

Amount of Infestation in Treated Plots.—The fruit in the experimental series was harvested five times. The following method of picking samples was used to obtain the data shown in table 3. The four middle rows in each plot were used as count areas. Fifty mature green fruits were picked from each row. Within each row 10 fruits were picked from the sixth, seventh, eighth, ninth, and tenth vines. The fruit was picked at random, but an effort was made to pick five fruits from each side of each vine in the count area.

The summary of results in table 3 shows that plants dusted with calcium arsenate yielded fruits having the lowest amount of injury. The next most effective treatment was the heavy application of 40 per cent cryolite. The 80 per cent cryolite was nearly as effective as the heavy application of 40 per cent cryolite, and the least efficient was the light application of 40 per cent cryolite. The total amount of active ingredient

TABLE 3

PERCENTAGE OF INJURED TOMATOES* FROM PLANTS IN EXPERIMENTAL PLOTS, BRENTWOOD, 1939

Treatment†	September 25		October 10		October 20		November 3		November 14		Seasonal average	
	Wormy	Stung‡	Wormy	Stung‡	Wormy	Stung‡	Wormy	Stung‡	Wormy	Stung‡	Wormy	Stung‡
Check, untreated	13.25	15.25	9.87	15.56	13.56	14.12	11.68	12.00	10.56	13.75	11.78	14.13
Undiluted calcium arsenate	3.37	5.62	2.33	4.25	2.91	4.58	2.66	2.08	2.16	3.41	2.68	3.99
80 per cent cryolite	7.12	13.50	5.50	9.00	5.62	6.62	4.25	6.37	3.87	7.00	5.27	8.49
40 per cent cryolite	7.25	10.00	6.25	10.62	4.62	12.87	6.25	10.75	4.75	9.50	5.82	10.75
40 per cent cryolite heavy	7.62	8.00	4.50	9.37	3.75	6.87	3.50	5.87	3.25	8.50	4.52	7.72

* Pearson variety harvested green for eastern shipment.
† For amounts of insecticides applied, see table 2.
‡ Includes other superficial worm injury.

applied to the plant was about the same in the plots receiving 80 per cent cryolite and the heavy application of 40 per cent cryolite (table 2).

Amount and Persistence of Insecticide on Foliage.—The frequency with which an insecticide must be used is influenced by the amount of toxic substance applied, its persistence upon the treated plants, and plant growth. In order to determine the persistence of the calcium arsenate and the cryolite used in the present experiments, samples of tomato leaves were taken from treated vines at six different times during the harvest season. Five leaves were removed at random from each of the four replications of a given treatment, placed in a paper bag, and brought to the laboratory with minimum disturbance.

For arsenic analysis,[6] the leaves were dipped in warm dilute nitric acid solution until the first traces of brown coloration appeared upon the surface. They were rinsed in fresh nitric acid solution, the rinsings were combined with the original acid solution, and 20 cc of concentrated sulfuric acid was added. The total volume was evaporated twice to white

[6] Mr. J. W. Hansen of the Division of Entomology and Parasitology made the analyses for arsenic and fluorine.

fumes to ensure destruction of all nitric acid, and the arsenic was then distilled according to the customary method (Association of Official Agricultural Chemists, 1935). Final determination of arsenic was made by titration with standard bromate solution.

For fluoride analysis, the leaves were dipped in hot alkaline soap solution (25 cc of 30 per cent sodium hydroxide, 25 cc of 10 per cent sodium oleate, 200 cc of water) for 20 seconds, removed, and rinsed with a spray of hot normal sulfuric acid. The soap solution and acid rinsings were

TABLE 4

AMOUNTS OF INSECTICIDES UPON TOMATO LEAVES EXPRESSED IN MICROGRAMS OF ACTIVE INGREDIENT PER SQUARE INCH*

Insecticide	Sept. 8	Sept. 20	Sept. 27	Oct. 11	Nov. 3	Nov. 14
Commercial calcium arsenate as arsenic	34	11	72	7	68	36
80 per cent cryolite as fluorine..........	80	28	82	5	67	1
40 per cent cryolite as fluorine..........	49	15	34	0	39	31
40 per cent cryolite as fluorine (extra-heavy application)..................	45	17	29	3	28	32

* Dates dusted: Sept. 8. Sept. 27, Oct. 12. For amounts applied see table 2. Samples secured on day of dusting were taken after dust was applied.

combined, cooled, and made up to 500 cc. A desired aliquot, usually 100 cc, was acidified, extracted with 40 cc of an equal mixture of petroleum ether and ethyl ether to remove waxes, and treated with 25 cc of saturated potassium permanganate. After heating for 20 minutes, the precipitated manganese dioxide was filtered out, the solution treated with 60 cc of concentrated sulfuric acid and distilled from a Claisen flask at a temperature of 135–145° centigrade. Water was added as required to maintain the temperature, until the volume of distillate was 250 cc. This was then brought to the desired pH and titrated with standard thorium nitrate solution (Hoskins and Ferris, 1936). In all cases, appropriate blank determinations were made and necessary corrections applied.

In order to determine the area of the dusted leaves, they were rinsed after removal of the insecticide, allowed to drain, and then spread upon heavy paper and traced with a pencil. A planimeter was used to determine the area, and the figure thus obtained was doubled to allow for both upper and lower surfaces.

The results of dividing total deposit by total area, that is, the deposits per square inch, are given in table 4. The characteristic decrease after dusting and rise at the next application are well shown. The effect of a heavy rain (1.03 inches on October 2 plus 0.33 inch 3 days later) is shown by the small amounts of the insecticides present on October 11. On the other hand, after the long dry interval from dusting on October

12 to sampling on November 3, relatively heavy deposits were still present.

Comparison with table 2 brings out the important point that arsenic, though used in the smallest amounts, was present in quantities often equal to or larger than those of the other insecticides. This condition was particularly marked as the season advanced. Hence it may be concluded that under the conditions of these experiments, calcium arsenate is more efficient than cryolite in depositing upon and adhering to tomato leaves, and the better control secured with this material is doubtless due in part to its superiority in these two respects.

The heavy applications of the 40 per cent cryolite dusts resulted in less injured fruit, but the deposit upon the leaves was no heavier than that from the ordinary applications. This apparent discrepancy is probably due to more uniform distribution with the heavier application, resulting in better control but not necessarily leading to higher deposits per unit of surface.

REMOVAL OF ARSENIC RESIDUE

Because of the poorly applied, excessive amounts of calcium arsenate frequently encountered in the field, it was thought advisable to make some tests of residue removal.[7] Samples of tomatoes were collected from dusted plants in commercial fields. A visual selection of the most heavily dusted fruit that could be found and of the fruit with an average coverage was made. One set of samples was bruised by slitting the tomatoes on both sides with a knife, after which the fruits were placed in no. 10 cans, compressed, and allowed to stand overnight. This was done to simulate the effect of bruising tomatoes during shipment to the cannery. All samples were soaked in water for 2 minutes with agitation and overflow, and then sprayed for 1 minute under a tap. The whole tomatoes were then ground in a meat chopper and samples taken from each lot for arsenic determinations. The results were as follows:

Condition of fruit and residue	Arsenic, as arsenic trioxide, in grains per pound
Fruit bruised:	
Heavy residue	0.022
Medium residue	.012
Light residue	.003
Fruit unbruised:	
Heavy residue	.011
Medium residue	.006
Light residue	0.002

[7] This work was carried on in coöperation with the National Canners' Association Laboratories. All analytical work here reported was done by Mr. F. C. Lamb of that laboratory.

When the fruit was badly bruised, arsenic removal was more difficult than when the fruit was not injured: whereas the unbruised fruit with medium residue contained only 60 per cent of the tolerance, bruised fruit exceeded the tolerance (the present tolerance is 0.01 grain arsenic trioxide per pound). But with heavy residue, the washing used in these tests was not sufficient to reduce the arsenic below the tolerance on either bruised or unbruised fruit.

Further work with grower-dusted tomatoes was impossible because of rains.

To obtain further information, a portion of a field was heavily dusted on October 2. Unfortunately, rain occurred that night, but not in sufficient quantity to wash much dust from the tomatoes. Samples were picked on the morning of October 4 and handled in the same manner as commercially picked fruit. After four lug boxes of the most heavily coated fruit were picked, a portion of the experimental area was again dusted and four more lug boxes of fruit picked. There was considerable dew, and in picking the fruit the calcium arsenate was well smeared over the surface. It formed a paste in some cases and probably stuck to the fruit better than it would have done on dry fruit.

Samples of the fruit which had been dusted once and of that which had been dusted twice were run through two commercial cannery washers. The remainder of the fruit was taken to the National Canners' Association Laboratory. One set of samples was given an acid wash, which consisted of immersing the tomatoes for 1 minute in a 1 per cent hydrochloric acid solution agitated continuously. This was followed by a 2-minute, agitated water wash, and finally the tomatoes were slowly rotated under a water spray for 2 minutes. All washed samples were steamed for 1 minute in an autoclave, hand-peeled, and hand-cored by methods approximating commercial practice. One set of samples was unwashed.

Arsenic determinations were made on whole fruit of the unwashed samples and separately on the peeled fruits and on the peelings and cores of the cannery-washed and acid-washed samples. The total amount of arsenic on the whole fruit in any given sample was calculated. The results of these tests are given in table 5. On the fruit receiving an acid wash, the arsenic was reduced below the tolerance. The cannery water wash removed much of the arsenic but did not reduce it below the tolerance. Most of the residue was in the peeling and cores, so that if these parts were discarded and only the peeled fruit used, the residue was not excessive.

According to these results, so much dust may be applied to tomatoes

that the average cannery washer is unable to remove it sufficiently. The fruit used in the second series of experiments (table 5) was covered with maximum amounts of dust. Only in scattered portions of a very poorly, heavily dusted field would such a condition prevail. It represents the extreme, but points out the fact that there is danger in improper use of calcium arsenate dusts. Fruit should never be dusted enough to show white in the box; in fact, fruit going to the cannery in that condition is

TABLE 5

ARSENICAL ANALYSES OF VARIOUSLY TREATED TOMATO FRUITS*

Number of dustings and type of wash	Arsenic trioxide, in grains per pound		
	Peeled fruit	Peel and cores	Whole fruit
One dusting:			
Unwashed	——	——	0.417
Acid-wash, laboratory	0.0039	0.047	.0099†
Cannery wash, plant A	.0037	.093	.0158†
Cannery wash, plant B	.0037	.093	.0171†
Two dustings:			
Unwashed	——	——	.532
Acid-wash, laboratory	.0022	.035	.0066†
Cannery wash, plant A	.0037	.058	.0115†
Cannery wash, plant B	0.0030	0.104	0.0173†

* Data from National Canners' Association Laboratories.
† Calculated.

likely to be rejected by the canner. If dust is evenly applied, there is no danger of a residue problem in canning tomatoes (Michelbacher and Essig, 1938). The average cannery washer will remove any reasonable amount of dust. Where worm infestations are serious in the northern producing section, control measures are necessary during harvest; but considerable care should be exercised in applying poisonous dusts then.

With tomatoes grown to be marketed as green fruits, special attention should be given to residue removal. Where fields have been dusted during harvest, the fruits must be washed or wiped.

RECOMMENDATIONS ON CORN-EARWORM CONTROL

The importance of proper applications of insecticidal dusts for corn-earworm control cannot be overemphasized. Thorough distribution with proper equipment will insure efficient control, savings in materials, and the elimination of complicating dust residues. The tendency in many fields is to attempt to compensate for what is lacking in either equipment

or careful operation by using excessive amounts of dust. Such procedure is not recommended. If the vines are completely covered with not more than 15 to 25 pounds of calcium arsenate per acre, preferably when dew is on the plants, a high degree of control may be expected. It is not necessary to concentrate materials on the fruits—this is in fact an undesirable practice.

The dusts used in the control of tomato insects are poisonous, and when weather conditions suitable for dusting occur, the operators of equipment are exposed to the dust for long periods. Because of the danger of taking in the poison through the mouth and nose, workers should be supplied with some kind of dust mask. Masks are available which give sufficient protection without causing much annoyance to the operator.

In previous experimental work with canning tomatoes, good control was obtained with fluosilicate dusts (Michelbacher and Essig, 1938). With large vines, 40 per cent barium fluosilicate and 40 per cent cryolite dusts have given good control when used at the rate of 30 pounds to the acre. Of the fluosilicates, cryolite is most extensively used. This material should not be used at a strength of less than 40 per cent, and it is probably desirable to use it at a strength of 50 to 70 per cent. As the active ingredient in this dust is increased, smaller amounts are required per acre, but the dusting characteristics become less desirable and the dust is more difficult to apply evenly.

Calcium arsenate is as easily applied as any of the effective materials tested and has proved more effective against hornworms than the fluosilicates. Hornworms are among the most destructive insects attacking tomatoes over a large portion of the northern tomato-producing section. Growers in this region can obtain satisfactory control of both corn earworms and hornworms with calcium arsenate dust properly applied.

SUMMARY

The tomato pinworm has not been a serious pest in the northern tomato-producing section of California. Over a part of the area it has never been found; it is abundant only in Merced and Madera counties, where it does not appear in destructive numbers until the shipping crop is nearly harvested.

The potato tuber moth was found most abundant in the coastal counties, where it caused only a very small amount of damage.

Tomato and tobacco hornworms, during the past season, were relatively scarce, and damage was the smallest observed since this investigation was started in 1935.

The beet armyworm was more abundant than at any other time since

1935. This insect was responsible for some superficial injury to the fruit. Other species of armyworms were present, but did little damage.

The corn earworm was more abundant in 1939 than in 1938, and exclusive of stung and superficially injured fruit, injury amounted to as much as 28.5 per cent.

The corn-earworm moths have two flight habits. If, upon emerging, adults find host plants in suitable condition for oviposition, they make only short flights; if host plants are not present, the moths may make long flights, traveling many miles from the place of emergence.

Experimental work carried on at Brentwood has shown that the time and degree of infestation varies so greatly from year to year and from field to field in any given year, that each field must be examined carefully to determine the need and time for applying control measures. Calcium arsenate proved to be the most effective of the insecticides used against corn earworm in the experimental plots at Brentwood. Data are given on the amounts of arsenic and fluorine present on dusted leaves at various times during the harvest season.

The average cannery washer will remove any reasonable amount of residue; but when applications are poor and the fruit is heavily loaded with dust, the average cannery washer probably will not adequately remove the arsenic.

For good control, good equipment and careful application, as well as an effective insecticide, are needed.

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